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Integrating Garlic (*Allium sativum*) and Ginger (*Zingiber officinale*) into Diabetes Care: sA Therapeutic Approach

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Diabetes mellitus is a chronic metabolic disease that is associated with chronic hyperglycemia caused by the lack of sufficient insulin release, insulin resistance or both. It causes significant burden of health worldwide and the complications that include neuropathy, retinopathy, and cardiovascular diseases. Synthetic antidiabetic medications have undesirable effects when used over a long period, so using the natural therapeutic options is worth investigating. The proposed study attempted to compare the antidiabetic, hepatoprotective, and hematological properties of garlic and ginger extracts when given alone and in combination on diabetic rats which were fed alloxan. A total of 30 male Wistar were randomly selected and divided into five groups (n = 6) normal control (T_0), diabetic control (T_1), diabetic + garlic extract (T_2), diabetic + ginger extract (T_3), and diabetic + garlic + ginger mixture (T_4). Alloxan monohydrate (150 mg/kg) induced diabetes through the single intraperitoneal injection. Extraction was given as oral extracts at a dose of 6g/kg over a period of 28 days. Blood glucose, HbA1c, lipid profile (HDL, LDL, VLDL), liver enzymes (ALT, AST, ALP), and hematological indices (Hb, RBC, WBC, platelets, HCT) evaluated during day 0, 14 and 28. One-way ANOVA test was used to analyze data with the help of the post-hoc test being performed with the significance being accepted at $p < 0.05$. Upon 28 days of therapy, there was a significant decrease in fasting blood glucose (112.4 ± 4.6 mg/dL) and HbA1c (6.1 ± 0.3%) in the combination group (T_4) as compared to the diabetic control (T_1: 248.7 ± 6.2mg/dL and 9.8 ± 0.4per cent). The T_4 group showed a significant increase in HDL (49.9 ± 2.1 mg/dL), a decrease in LDL and VLDL (62.4 ± 3.5 mg/dl and 23.9 ±2.3mg/dl, respectively), and a significant change in HDL levels was observed ($p < 0.05$). The hepatoprotective and hematopoietic effects were demonstrated by the restoration of liver enzyme activities (ALT, AST, and ALP) and hematological parameters (Hb, RBC, WBC, platelets, HCT) in T_4 to control values of normal levels. The Garlic and ginger extracts especially in combination with each other were effective in glycemic control, lipid metabolism, and hematological profiles of diabetic rats. These results justify their possible application as natural adjunct therapy in the treatment of diabetes.

Keywords: Diabetes mellitus, garlic, ginger, hyperglycemia, lipid profile, hematology, antidiabetic.

INTRODUCTION

The problem of diabetes mellitus is one of the significant public health issues of the twenty-first century, a persistent hyperglycemia caused by the inability to secrete insulin or develop insulin resistance or both (Pearson, 2021). The past history of diabetic complications was characterized by microvascular complications like nephropathy, retinopathy, and neuropathy and macrovascular complications like coronary artery disease and stroke. Nevertheless, recent epidemiological data suggest that the morbidity and mortality among diabetic individuals have changed, and more and more cancer, dementia, and other chronic illnesses are observed as life expectancy increases (Chatterjee et al., 2016; Pearson et al., 2021). The mentioned trends emphasize the necessity of new therapeutic methods that would tackle metabolic dysregulation and oxidative stress as the main factors of both classical and emerging diabetic complications.

Eating change is one of the multiples of diabetes prevention and control. The decrease in the rates of type 2 diabetes mellitus (T2DM) and cardiovascular disease caused by the nutritional models like the Mediterranean diet (MD) is due to

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the high levels of polyphenols, phytosterols, and monounsaturated fatty acids (Estruch et al., 2013; Salas et al., 2014). These bioactive substances ameliorate the endothelial activity, minimize oxidative stress, and elevate insulin sensitivity (Urpi et al., 2012). Phytochemical classes are similar organosulfur-based and phenolic antioxidants are very common in garlic (Allium sativum) and ginger (Zingiber officinale). Accordingly, the health promotion effects of the MD present a scientific explanation of why ginger and garlic can be examined as a functional plant-based intervention against metabolic stress associated with diabetes.

Garlic is one of the most ancient medicinal plants that have diverse biological properties such as antihyperlipidemic, antihypertensive, antioxidant, and antidiabetic prestige. Allicin and hydrogen sulfide (H_2S) are its principal bioactive ingredients that enhance insulin sensitivity, insulin release, and glucose metabolism (Emami et al., 2017; Petropoulos et al., 2018). Mechanistically, allicin facilitates the synthesis of nitric oxide (NO) and H_2S, which result in vasodilation and better vascular function remains even more applicable to decreasing cardiovascular risk in diabetes (Szulinska et al., 2018). These are the properties which suggest that garlic can be a promising natural agent in the area of metabolic and endothelial protection.

Ginger is a rhizomatous plant that contains a high concentration of phenolic components such as gingerols, shogaols and paradols and it also shows a major pharmaceutical activity against metabolic disorders. Its bioactive components are involved in glucose transporter, peroxisome proliferator-activated receptor gamma (PPARγ), inhibitions of hepatic gluconeogenesis and antioxidant enzyme actions (Ajanaku et al., 2022). Ginger enhances glycemic regulation, lipid metabolism, and insulin signaling through these pathways and delays the effects of oxidative stress and chronic inflammation in diabetes.

Though both garlic and ginger have been widely investigated independently, with regards to their therapeutic attributes on antidiabetic and cardioprotective properties they possess, very minimal research has been conducted on their synergistic effect on therapeutic applications. Their unique but complementary action targeting insulin secretion and lipid destructions in garlic and glucose uptake and antioxidant protection in ginger may lead to a synergistic action that is better than using either extract by itself (Arslan et al., 2025).

The current research project was aimed at assessing the antidiabetic, hepatoprotective and hematological properties of ginger and garlic extracts separately and in combination with each other in alloxan-induced diabetic rats.

MATERIALS AND METHODS

***Ethical consideration/approval*:** Before starting the in-vivo study, ethical approval were taken from the Ethical Institution Review Board of MNS-University of Agriculture Multan.

***Preparation of raw materials*:** Raw materials were procured from the local market of Multan. Garlic and ginger were cleaned before being converted into powder. A predetermined quantity of the powder was dissolved in distilled water using a magnetic stirrer to create an extract of garlic and ginger. The extract was then filtered, evaporated to dryness, and an aqueous suspension was prepared to facilitate handling.

***Preparation of extracts*:** Extraction of phytochemicals from ginger and garlic that was carried out by the method of methanol extraction using a fine powder dissolved in methanol by 10:90 ratios in a conical flask and tightly sealed with aluminum foil and set in vibrator at 2000 rpm for 6 hours then removed from vibrator and leave 30 minutes for rest. Then solutions were filtered from what 30 man filter paper No. 1. After filtration solution were set in rotary evaporator for 10 minutes at 400C bath temperature 120rpm/min. Then concentrated liquid extracts were prepared (Elfalleh *et al.,* 2012).

***Experimental animal selection and standardized housing conditions*:** The rat room at the department of Human Nutrition & Dietetics, MNS-University of Agriculture Multan was served as the study's location. Male Albino Rats (25) with weight of around 80-120g were purchased from University of Lahore and were housed in an environment with humidity and temperature level of 55 to 60 percent and 25°C and a 12-hour day/night cycle. They were kept in air-conditioned polycarbonate cages that included feeding bowls and glass water bottles. Before starting experiment, rats were acclimated for seven days prior to experiment in order to removing any underlying infections. All of the rats' basal diet and clean water needs were met during the acclimation period (Gogoi *et al.,* 2017).

***Diet composition*:** Basal diet was comprised of (g/1000g of diet) corn starch 750; casein 100; corn oil 100; vitamin mixture 30 and mineral mixture10 (Aguiar *et al.,* 2022).

***Induction of diabetes*:** Twenty five male adult Albino Wistar rats, weighing 170 to 180g, were used and divided into four groups of five each (G_0, G_1, G_2, G_3 and G_4). One group served as the control and healthy group, which was fed a basal diet, while the other treatment groups were 31 administered 65 mg/kg BW of Alloxan monohydrate via intraperitoneal injection for the induction of diabetes. Tests were performed after one week to assess diabetes (Soni *et al.,* 2019).

***Experimental design*:** This study aimed to evaluate the effects of garlic and ginger extracts on blood glucose levels. Following confirmation of elevated glucose levels, rats in Group 3 (G_3) received 6g garlic extract, Group 4 (G_4) received 6g ginger extract, and Group 5 (G_5) received both 6g garlic and 6 g ginger extracts. HbA1c levels were monitored weekly, and final results were analyzed after 40 days. A specific diet was administered to all rats' post-group assignment. The rats were randomly divided into five experimental groups, each consisting of five rats. The intervention aimed to assess the potential antidiabetic effects of garlic and ginger. The study

focused on tracking glycemic control through HbA1c analysis (Abdel-Daim *et al.,* 2020).

Table 1. Experimental design showing control and diseased groups with different dietary treatments including garlic, ginger, and their combination in diabetic rats.

Control Group		Diseased Group		
Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**
Basal diet	**Basal diet**	**Garlic extract**	**Ginger extract**	**Garlic & Ginger extract**
Healthy rats received basal diet as a healthy control group	Diabetic rats received basal diet without any treatment	6g/kg BW	6g/kg BW	6g/kg BW + 6g/kg BW+ Basal diet

***Determination of total phenolic contents (TPC)*:** Razzaq et al. (2013) modified the Folin Ciocalteu (FC) method to evaluate the total phenolic contents (TPC) of the ginger and garlic extract. In an eppendorph tube, take 300µL of the supernatant that was extracted. Add 600µL of the 10% F-C reagent and mix by vortexing. Following a vortex, add 700 mM Na2CO3 (2400µL) solution, well mix, and let it sit at room temperature in a dark area for half an hour. Using an Epoch Eliza reader (BioTec Instruments, Inc., Winooski, VT, USA), the absorbance of a 200µL sample was measured at 765 nm and quantified in mg GAE 100g-1.

***Biological Assays*:** During the course of the 28-day study, each rat's weight and daily feed intake were recorded, and they underwent physical examinations every week. They were fed 25 grams per kilogram of body weight on a regular basis. Feed intake and body weight were evaluated. Their samples of blood were taken on 0 day, 14th day, and 28th day during the study period for phytochemical and biochemical analysis (liver function and lipid profile tests) (Rabeh *et al.,* 2019).

***Hematological Investigation*:** For the hematological investigation, the complete blood count (CBC) is performed using the methodology described in (Rabeh *et al.,* 2019). It supports the clinical assessment of any illness or infection. It consists of Hemoglobin (Hb), Red Blood Cells (RBC), White Blood Cells (WBC), Hematocrit (HCT) and Platelets.

***HbA1C*:** Blood sample is transferred, to a specialized tube or container containing, an anticoagulant, to prevent clotting. The sample is centrifuged to separate the blood cells from the plasma or serum. The separated blood cells or hem lysate are mixed with a reagent that releases hemoglobin from the red blood cells. The mixture is then subjected to chromatography (e.g., high-performance liquid, chromatography (HPLC) or immunoassay) to separate, and measure the glycated, hemoglobin (HbA1c) fraction. The instrument is calibrated using certified reference materials to ensure accurate results. The HbA1c result is calculated as a percentage of total hemoglobin, typically reported as a percentage (e.g., 6.5%). Glycosylated hemoglobin test will be used to assess blood glucose level (Sultana, S (2014).

***Hemoglobin (Hb)*:** The center graduated tube was filled with 0.1N HCl (1%) up to mark 2. The sahlis pipette was used to precisely draw up the blood to mark 20 (20 µl). Blood was moved from the pipette to the hemometer's central graduated tube. With the aid of a stirrer, it was well combined and given two minutes to react. Drop by drop, distilled water was added and well mixed until the color matched that of the Standard comparator tube. It was removed since the color matched, and the results on the side were noted (Rabeh *et al.,* 2019).

***White blood cells (WBCs)*:** Up to 0.5 marks, blood was taken into a WBC pipette. WBC dilution fluid up to eleven markings was taken right away. The pipette was moved horizontally between thumb and finger. A 1:20 dilution was attained. The hemocytometer was put on top of the counting chamber cover slip. The pipette's fluid was released at a 45º angle. WBCs were tallied in the counting chamber's four main squares (there were sixteen little squares) (Rabeh *et al.,* 2019).

***Red blood cells (RBCs)*:** Up to the 0.5 point, blood was drawn into the RBC pipette. Up until mark 101, RBC diluting fluid was applied. One turned the pipette. This resulted in a 1:200 dilution. The counting chamber was covered with the cover slip in place. By maintaining the pipette at a 45º angle, blood was introduced to the measuring chamber and counted (Rabeh *et al.,* 2019).

***Hematocrit (HCT)*:** A micro hematocrit (3/4th) tube was filled with blood and sealed with sealer. In a hematocrite centrifuge, the hematocrit tube was spun for four to five minutes at 2000 rpm. A hematocrit reader was used to read the value, and the outcome was noted (Rabeh *et al.,* 2019).

***Platelets (PLT)*:** Phase-contrast light microscopy was used to count platelets after a tiny amount of diluted blood was subjected to a red cell destroying reagent, such as ammonium oxalate, in a calculating chamber (hemocytometer). The dilution factor was then applied to the count (Rabeh *et al.,* 2019).

***Biochemical investigation*:** Biochemical investigation includes total cholesterol test, liver enzymes and kidney function test.

Liver function test (LFT)

***Alanine amino transferase (ALT)*:** Serum ALT levels were measured using calorimetry. Blank, sample, and standard tubes were made and marked individually. 100 µl each of the blank, sample, and standard were combined with 500 µl of the chromogenic reagent. To the sample alone, 5 milliliters of NaOH with a Normality of 0.4 was applied. Every solution was allowed to sit at room temperature for fifteen minutes. The absorbance, of the sample and the standard were contrasted (El-Demerdash *et al.,* 2005).

***Aspartate, amino transferase (AST)*:** AST level, was determined calorimetrically, with common diagnostic, equipment. Three, tubes, designated as blank, sample, and standard, held 500 µl of color reagents each. Five milliliters

of a 0.4N NaOH solution were added to the sample tube. Each of the three tubes received a matching 200 µl of serum. Both the sample's and the standard's absorbance levels were noted (El-Demerdash *et al.,* 2005).

***Alkaline phosphatase (ALP)*:** Commercial clinical diagnostic kits tested ALP levels using calorimetry. Each of the three blank tubes labeled, samples, and standard contained 500, µl of the chromogenic, reagent. To the sample tube, 5 ml, of 0.4 N NaOH solution was added. 200, µl of serum, were added, to each tube. Both the standards' and the samples' absorbance values were recorded (El-Demerdash *et al.,* 2005).

Renal function test

***Creatinine*:** To determine Creatinine levels in the bloodstream of rats, Merck Professional Kits were used. 100 µl apiece of distilled water, serum and creatinine standards were added into 3 test tubes. The tubes were stirred. The absorption of the sample versus the standard and blank was detected at 492nm (Irshad *et al.,* 2018).

***Blood urea nitrogen (BUN)*:** Merck Commercial Kits were utilized to ascertain the amount of urea in the rats' serum. One reagent and one additional reagent were used, and they were thoroughly combined in a 4:1 ratio, respectively. Three test tubes were filled with a 1000 µl of reagent, 10 µl sample and distilled water. The test tubes were incubated for five minutes at 37°C in an incubator. A chemistry analyzer was used to obtain the readings (Irshad *et al.,* 2018).

***Total cholesterol test*:** Total cholesterol was calculated according to the method described by (Qadir *et al.,* 2024), 1 mL of cholesterol reagent was mixed with 1µL of serum or cholesterol standard (200 mg/dL) and vortex right away. At room temperature, standards and samples were allowed to incubate for ten minutes. Using cholesterol reagent as a blank, absorbance was determined with a spectrophotometer at 500 nm. Instead of using cholesterol reagents, triglyceride reagent (Stanbio No. 2150) and standards were used to measure serum triglycerides as previously described. Measurements of absorbance for triglycerides and total cholesterol were adjusted (due to hemolysis) using the absorbance of a serum blank that was made with 1 milliliter of physiological saline and 1 liter of serum. Serum blanks were made for every sample of serum. Each serum sample had a set of sterile blanks ready. Total cholesterol and triglycerides were determined by using equation. Total cholesterol or triglycerides = Unknown Abs - Serum blank Abs / Standard Abs x 200.

***HDL-cholesterol*:** The method outlined by Chacrabati et al. (2022) was utilized to calculate the HDL cholesterol. By using the magnesium chloride/dextran sulphate technique, non-HDL-C was precipitated to calculate HDL-Cholesterol. One l00µL of serum was mixed with l0µL of the precipitating reagent. After being vortexes, for five minutes, the samples were left to stand. The non-HDL-C in the samples was separated using a centrifuge machine that ran the samples at 15,000 rpn1 for two minutes. Subsequently, 1 milliliter of cholesterol reagent was combined with 25 microliters of either serum or HDL-C standard, and 10 minutes of ambient temperature were given to the mixture. A 500 nm absorbance measurement was made using cholesterol reagent as a blank. HDL-C was determined by using equation: HDL-C = Unknown abs/standard abs x 55

***LDL and VLDL cholesterol*:** The friedewald calculation was used to determine VLDL cholesterol and LDL cholesterol levels (Tobert, 2022). LDL cholesterol = Total cholesterol – HDL – V LDL Very low density lipoprotein = Triglycerides/5

***Statistical analysis*:** Software was used to evaluate the data (Statistics 8.1). Two-way ANOVA was the statistical test employed for the analysis of variance. In every instance, the threshold of $p < 0.05$ was established for statistical significance. The data was replicated for every analysis and reported as mean standard deviations (± S.D). The mean comparison was conducted using the Latin Square Design test (Montgomery, 2017).

RESULTS

***Total Phenolic Content and Total Flavonoid Content of Extract analysis*:** Significant alterations between treatments are shown by the Total Phenolic Content (TPC) analysis, which is shown in Table 2. The amalgamation management of ginger and garlic ($T_{Ginger+Garlic}$) had the maximum phenolic concentration, assessing 314.61 ± 0.02 mg GAE/g. This extraordinary number points to a potential synergistic interaction between allicin and gingerols, two favorable complexes found in both garlic and ginger. While ginger (T_{Ginger}) showed a comparatively lesser content of 100.41 ± 0.02 mg GAE/g, garlic only (T_{Garlic}) showed a substantial TPC of 155.85 ± 0.11 mg GAE/g. These consequences are consistent with those of Ghasemzadeh et al. (2010), who establish that garlic's antioxidant ability is recognized to its high content of phenolic chemicals, particularly allicin.

Table 2. Mean comparison for total phenolic content (mg GAE/g) and total flavonoid content (mg GAE/ g).

Treatment	Total phenolic content (mg GAE/g)	Total flavonoid content (mg GAE/g)
T_{ginger}	100.41 ± 0.02	88.55 ± 0.12
T_{garlic}	155.85 ± 0.11	205.80 ± 0.08
$T_{ginger+ garlic}$	314.61 ± 0.02	168.14 ± 0.02
Total	3.52 ± 0.03	3.71 ± 3.72

The antioxidant profile of the treatments is further disclosed by the total flavonoid content (TFC) data. With the maximum flavonoid content of 205.80 ± 0.08 mg QE/100g, garlic (T_{Garlic}) once again takes the lead, monitored by the combination treatment ($T_{Ginger+Garlic}$) at 168.14 ± 0.02 mg QE/100g. The lowest TFC was noted by ginger alone (T_{Ginger}), at 88.55 ± 0.12 mg QE/100g. These consequences imply that ginger does not add as much to the flavonoid concentration as

garlic does. The mutual treatment's comparatively high flavonoid content nevertheless illustrates the possible synergistic effects of both constituents. The study by (Sagar *et al.,* 2020) which proved that garlic has significant levels of quercetin and other flavonoids that give it its health-promoting qualities, provisions this.

Effect of extracts on biological parameters for diabetes

***Effect on hemoglobin (Hb) Level (g/dL)*:** Hemoglobin is an orbicular protein that aids carry oxygen from the lungs during the course of the body. The ANOVA outcomes revealed extremely significant effects ($p < 0.01$) for treatment, days, and their interaction on hemoglobin ranks, as indicated in Table 3. Strong statistical confirmation that the types and length of treatment had a considerable impact on the Hb meditation is indicated by the extremely low p-values (0.0000) and high F-values. This over time authenticates the efficacy and dependability of the investigational treatments. Through the 28-day study period, the diabetic mice in the untreated group (T_1) sustained continuously low Hb levels, accumulative only slightly from 11.95±0.03 to 12.01±0.06 g/dL, as seen by the mean comparison facts in Table 3. Hb points, on the other hand, significantly enhanced in rats given garlic (T_2), ginger (T_3), or a combination of the two (T_4). For illustration, the T_4 group's hemoglobin improved the maximum, from 11.95±0.03 g/dL on day 0 to 15.14±0.02 g/dL on day 28. While ginger alone (T_3) improved Hb levels from 11.75±0.02 to 13.96±0.07 g/dL, management with only garlic (T_2) raised levels from 11.84±0.02 to 14.23±0.02 g/dL. These conclusions imply that while ginger and garlic both have hemopoietin potentials on their own, they work best when organized. These consequences are reliable with those of Asdaq and Inamdar (2010), who found that the antioxidant and antidiabetic possessions of garlic and ginger supplementation greatly improved hematological limitations in diabetic rats.

The presence of an amalgamation garlic-ginger therapy group (T_4), which indicated a more obvious improvement in Hb than garlic alone, signifies a significant distinction between the current study and the mentioned work. This study showed that ginger and garlic, predominantly when collective, greatly raise hemoglobin levels in diabetic mice. The findings provide credence to the consumption of these natural extracts as adjunctive treatments for the management of problems accompanying with diabetes. The beneficial potential of these natural ingredients is highlighted by the high consequence levels and stable enhancement over the course of all treatment times.

***Effect on red blood cells (RBCs) (x106/µL)*:** Red blood cells comprehend a protein called hemoglobin, which conveyances oxygen. It movements into the bloodstream after binding with oxygen in the lungs. The body's tissues and organs subsequently collect this oxygen. The ANOVA consequences in Table 3 indicate that the RBC amount was significantly impacted by the therapy, the days, and the interaction between the treatment and the day ($p < 0.01$). Days, interaction, and treatment all have very great F-values, and the p-values

Table 3: Storage study of different parameter's level in rats.

Parameters	Storage period (days)	Treatments					Storage mean
		T_o	T_1	T_2	T_3	T_4	
Hemoglobin (g/dL)	0	13.73^{f}	11.95^{h}	11.48^{i}	11.75^{j}	11.95^{h}	12.17
	14	13.83^{e}	12.00^{h}	14.02^{c}	13.56g	14.01^{c}	13.48
	28	13.90^{de}	12.01^{h}	14.23^{b}	13.96^{cd}	15.14^{a}	13.84
	Treatment mean	13.82	11.98	13.24	13.09	13.70	-
Red blood cells (x106/µL)	0	7.80^{c}	6.03^{i}	6.14^{h}	6.14^{h}	6.09^{hi}	6.44
	14	7.83^{c}	6.04^{i}	7.39^{f}	7.28^{g}	7.73^{d}	7.25
	28	7.93^{b}	6.11^{h}	7.82^{c}	7.65^{e}	8.08^{a}	7.51
	Treatment mean	7.85	6.06	7.11	7.02	7.30	-
White blood cells (x106/µL)	0	7.07^{f}	8.91^{e}	9.04^{c}	9.22^{a}	9.08^{b}	8.66
	14	7.04^{f}	9.05^{bc}	6.98^{g}	7.07^{f}	6.51^{k}	7.33
	28	6.91^{h}	9.01^{d}	6.82^{j}	6.87^{i}	5.96^{l}	7.11
	Treatment mean	7.00	8.99	7.61	7.72	7.18	-
Platelets (x103/µL)	0	820.14^{o}	902.00^{h}	955.20^{g}	990.80^{c}	992.40^{d}	932.10
	14	822.34^{m}	845.00^{l}	867.40^{k}	888.20^{j}	890.10^{i}	862.58
	28	823.33^{n}	995.30^{c}	999.40^{a}	998.30^{b}	960.10^{f}	955.28
	Treatment mean	821.93	914.10	940.60	959.10	947.50	-
HCT (%)	0	40.14^{g}	38.73^{i}	37.76^{i}	37.65^{i}	37.56^{i}	38.36
	14	40.56^{f}	38.33^{h}	41.25^{e}	40.9^{ef}	42.33^{d}	40.67
	28	40.61^{f}	38.49^{h}	44.33^{b}	43.36^{c}	46.46^{a}	42.65
	Treatment mean	40.43	38.51	41.11	40.63	42.11	-

Mean followed by different letters are significant ($p<0.05$); Each value is average of minimum three replicates

(0.0000) show very significant statistical implication. This recommends that the generous of treatment and how long it lasted were significant influences in altering the experimental animals' RBC levels.

These consequences are corroborated by the mean RBC levels shown in Table 3. Over the course of 28 days, the RBC in the healthy control group (T_0) improved slightly by nature, from 7.80±0.03 to 7.93±0.02 x10^6/µL. However, the untreated diabetic group (T_1) continued to have significantly lower values, fluctuating only from 6.03±0.02 to 6.11±0.04, suggesting that erythropoiesis was adversely impacted by diabetes. Significant improvement was made by the therapy collections, especially T_4, which had both ginger and garlic extract. Out of all the groups, this one had the maximum RBC count, rising from 6.09±0.04 to 8.08±0.03. Rats treated with garlic (T_2) had an improvement in RBC from 6.14±0.03 to 7.82±0.04, but rats treated with ginger (T_3) had a rise from 6.14±0.02 to 7.65±0.04. These findings establish that while ginger and garlic each have hematopoietic assistances on their own, their combination (T_4) has a synergistic influence that outperforms solo therapies.

Similar hematological compensations of ginger and garlic were also prominent in a study by Islam and Choi (2008) in rats with diabetes caused by alloxan. The antioxidant qualities of these botanicals were found to increase RBC, Hb, and packed cell volume (PCV) values. The dosage and length of treatment are where our results and those of Islam and Choi (2008) diverge most. The present study's larger dosage (6 g/kg BW) over 28 days led to higher RBC counts, predominantly in the combination group (T_4), indicating more dramatic efficiency, even though both studies verified hematological developments. These outcomes imply that extracts from ginger and garlic may diminish the effects of diabetes-induced anemia. The beneficial potential of these natural substances is confirmed by the consistently rising RBC counts and extremely significant statistical standards.

***Effect on white blood cells (WBCs) (x103/µL)*:** Immune cells known as white blood cells (WBCs) aid in protecting the body in contradiction of diseases. Granules comprehending protein-based enzymes are seen in certain WBCs known as granulocytes. These proteins aid in the devastation of viruses, bacteria, and other dangerous invaders. WBC levels were significantly obstructed by therapy, time (days), and their interaction, according to the ANOVA results showed in Table 3 ($p < 0.01$). Table 3 displays that on day 28, the WBC levels in the diabetic control group (T_1) rose from 8.91±0.03 to 9.01±0.02 ×10^3/µL, presenting that diabetes had activated the immune system and triggered inflammation. WBC levels, on the other hand, decreased slowly and steadily throughout the progression of the 28-day period in the treatment groups that received garlic (T_2), ginger (T_3), and a combination (T_4). The collective therapy group (T_4) experienced the most obvious drop, going from 9.08±0.01 to 5.96±0.04, representing strong anti-inflammatory potentials.

The WBC amount decreased from 9.04±0.02 to 6.82±0.01 after treatment with only garlic (T_2), and from 9.22±0.01 to 6.87±0.02 after treatment with ginger (T_3). The mixture in T_4 showed a synergistic effect, resulting in the maximum reduction in increased WBC levels, even though both solitary treatments were beneficial. This configuration is consistent with research by Tariq et al. (2021), who establish that extracts from ginger and garlic have anti-inflammatory and immunomodulatory possessions that enable diabetic rats' WBC levels return to normal. The size of the response is a significant difference between the cited study and the current one. Although Tariq et al. noted some minor modifications, the current study found that WBC amounts decreased more sharply and progressively, mainly in the T_4group.

This strength be because the current study used a larger dose (6 g/kg BW) and a longer treatment period. Extracts of ginger and garlic, especially when united, dramatically lowered increased WBC levels in diabetic rats, indicating potent immune-regulatory and anti-inflammatory possessions. These outcomes show how natural dietary changes can be used therapeutically to manage diabetes's immune-related difficulties. The efficacy of these plant extracts in reducing WBC abnormalities is confirmed by the regularly observed treatment trends and very significant statistical consequences.

***Effects on platelets (x103//µL)*:** Since platelets can form clots at damage sites, they are indispensable for preserving hemostasis. Damage to blood arteries reasons platelets to attach to the exposed area fast. Then, in order to stop extreme blood loss, they group together to create a plug. Table 3 displays the results of an assessment of the impact of ginger and garlic extracts on platelet counts in diabetic rats. Treatment, days, and their combination established extremely significant ($p < 0.01$) effects on platelet levels, according to the ANOVA. It is clear from Table 3 that the diabetic group's (T_1) platelet count grew affectedly, going from 902.09 ± 0.12 to 995.35 ± 0.01 ×10^3/µL by day 28. This recommends that diabetes caused a hypercoagulable state, which may have been brought on by inflammation and oxidative trauma.

On the other hand, the platelet amounts of treatment groups T_2 (garlic), T_3 (ginger), and T_4 (mixed extract) stabilized or decreased over time, signifying that these natural constituents have a protective and regulating function. The mixture treatment group (T_4) displayed a relatively concentrated platelet count (960.18 ± 0.08), while the garlic extract (T_2) demonstrated the most considerable drop by day 28 (999.44 ± 0.44), followed meticulously by ginger extract (T_3) with 998.37 ± 0.26. This implies that whereas distinct therapies initially increased platelet counts, the mixture assisted in preserving a more composed count, possibly as a consequence of the complementary anti-inflammatory and antioxidant possessions of ginger and garlic.

These consequences are reliable with those of a 2009 study by El-Sabban that examined the antithrombotic possessions of garlic in diabetic rats. According to their findings, garlic

stopped abnormal platelet count elevation and decreased platelet accumulation. Similarly, ginger's active constituents, such as gingerol, have been shown to prevent platelet beginning. The existing data show a larger regulatory consequence than their study, particularly in the combination group (T_4), which may be because of differences in dosage and treatment period.

In diabetic mice, the extracts of ginger and garlic, predominantly when combined, helped normalize increased platelet levels and lower the hazard of thrombosis. Because of the exceptionally low p-values and low mean square error (0.1), the outcomes were statistically extremely significant. These results lend credence to the therapeutic effect of dietary botanicals in reducing cardiovascular risk and regulating platelets in diabetic conditions.

***Effect on hematocrit (HCT) (%)*:** The percentage of red blood cells (RBCs) in the entire capacity of blood is known as the hematocrit. It is a fundamental sign of the body's ability to conveyance oxygen. Low hematocrit values could show blood loss or anemia. Elevated levels may be a sign of polycythemia or dehydration. In a complete blood count (CBC) test, it is frequently restrained. Over the course of 28 days, the influence of ginger and garlic extracts on diabetic rats' hematocrit (HCT) levels was evaluated. Treatment, days, and treatment-day interaction had a highly significant ($p < 0.01$) impact on HCT levels, according to the ANOVA consequences in Table 3.

The diabetic group without treatment (T_1) exhibited lower HCT standards during the trial period, from 38.73 ± 0.02% to 38.49 ± 0.59%, as indicated in Table 3. This recommends that anemia, which is commonly linked to diabetes, is triggered by hemolysis or withdrawn erythropoiesis. On the other hand, the HCT levels of the therapy groups (T_2, T_3, and T_4) significantly enhanced. At day 28, the collective extract group (T_4) had the highest value (46.46 ± 0.02%), followed by T_2 (44.33 ± 0.01%) and T_3 (43.36 ± 0.01%), representing that taking ginger and garlic together has a synergistic consequence.

Robust anti-inflammatory and antioxidant potentials found in both ginger and garlic may have helped to repair erythropoietin activity and lessen oxidative impairment to red blood cells. These consequences are consistent with earlier studies showing the hematological compensations of ginger and garlic. For example, a study by Qadir et al. (2024) presented that giving diabetic rat's powdered ginger and garlic greatly improved a number of blood indicators, counting HCT levels. According to the study's results, by strengthening antioxidant resistances and lowering oxidative stress, these natural enhancements may help manage the difficulties of diabetes.

The amalgamation of ginger and garlic (T_4) produced the most obvious increase in HCT levels when associated to the distinct treatments, demonstrating a synergistic impact. This development may be due to the combined antioxidant capacities of both herbs, which may rise erythropoiesis and lessen oxidative damage to red blood cells. The efficiency of these additions in discussing diabetes-induced hematological changes is established by the notable inequalities between the treatment groups and the diabetic control group.

***Effect on aspartate aminotransferase (AST) (µ/L)*:** Alpha-ketoglutarate and aspartate can be transformed into glutamate and oxaloacetate with the aid of an enzyme called aspartate aminotransferase (AST). The liver, kidneys, heart, skeletal strengths, red blood chambers, and brain are between the tissues that grasp it. Increased blood AST levels commonly show organ failure or tissue harm. Dependent on the clinical setting and related indications, such increases could be a mark of diseases such as liver or heart illness, renal or pancreatic anomalies, anemia, or musculoskeletal injuries. Table 4 shows how supplementing with garlic and ginger exaggerated the levels of aspartate aminotransferase (AST) in diabetic mice. Treatment, days, and their combination had highly significant ($p < 0.01$) possessions on AST levels, according to the ANOVA consequences.

Figure 1 demonstrations that the AST levels in the diabetic control group (T_1) decreased during the course of the 28-day period, going from 195.50 ± 0.20 µ/L on day 0 to 105.57 ± 0.32 µ/L on day 28. This reduction points to hepatic dysfunction, a frequent side effect of diabetes transported on by inflammation and oxidative stress. The treatment groups, on the other hand, shown progress. The assemblages who established garlic treatment (T_2) saw a decay from 196.30 ± 0.20 µ/L to 106.20 ± 0.60 µ/L, ginger treatment (T_3) saw a lessening from 198.27 ± 0.60 µ/L to 95.38 ± 0.53 µ/L to 90.75 ± 0.03 µ/L.

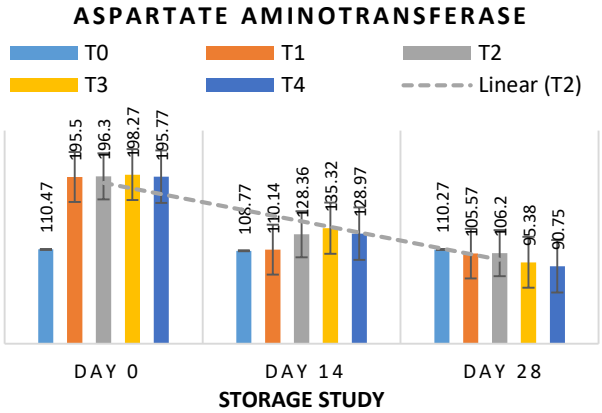

Figure 1. Effect on aspartate aminotransferase (AST) (µ/L).

These consequences are consistent with previous readings showing that ginger and garlic have hepatoprotective possessions. For instance, a study by Thomson et al. (2007) indicated that giving diabetic mice extracts of ginger and garlic significantly improved their liver enzyme profiles,

including their AST levels. According to the study's findings, by establishment antioxidant emplacements and lowering oxidative stress, these natural supplements may help achieve the difficulties of diabetes.

The amalgamation of ginger and garlic (T_4) produced the maximum obvious improvement in AST levels when compared to the individual treatments, indicating a synergistic effect. The combined antioxidant potentials of both basils may be responsible for this improvement, as they may lessen oxidative destruction to liver cells and stimulate hepatic function. The effectiveness of these extracts in treating diabetes-induced hepatic changes is established by the notable alterations between the treatment groups and the diabetic control group.

***Effect on alanine aminotransferase (ALT) (µ/L)*:** A transaminase enzyme recognized as alanine aminotransferase (ALT) is indispensable to the alanine cycle as it transmissions amino sets from alanine to alpha-ketoglutarate, which yields glutamate and pyruvate. This enzyme is indispensable for the digestion of amino acids and is mostly located in the liver. Raised serum ALT levels result from the release of ALT into the bloodstream initiated by severe liver cell destruction or necrosis. As a result, serum ALT measurement is frequently employed as a sensitive sign to evaluate liver function and identify liver destruction. A vital enzyme involved in the metabolism of amino acids, alanine aminotransferase (ALT) is mostly situated in the liver. Hepatocellular destruction or liver dysfunction are showed by elevated serum ALT levels. The ALT levels of the diabetic rats (T_1) in this examination were significantly higher than those of the healthy control group (T_0), approving that diabetes causes liver damage.

Remarkably, during the course of the 28-day period, ALT levels significantly reduced after treatment with garlic (T_2), ginger (T_3), and their combination (T_4), representing the potential hepatoprotective benefits of these extracts. Regarding ALT levels, the ANOVA results in Fig. 2 show extremely substantial differences ($p < 0.01$) across treatments, days, and their connections. The effectiveness of ginger and garlic in decreasing the liver damage linked to diabetes is established by the substantial reduction in ALT levels in treated groups when compared to the diabetic control group. The collective treatment group (T_4) demonstrated the most noticeable decrease in ALT levels by day 28, monitored by the ginger (T_3) and garlic (T_2) groups, rendering to an examination of the mean ALT levels. This recommends that when both extracts are used together, they will have a synergistic impact.

The protective influence of these natural extracts against diabetes-induced liver injury was shown by the fact that the diabetic control group (T_1) revealed persistently raised ALT levels through the research, whilst the healthy control group (T_0) maintained stable levels. According to a study by Thomson et al. (2007), for instance, garlic extract's antioxidant qualities were liable for the considerable decrease in blood ALT levels in streptozotocin-induced diabetic mice. Likewise, ginger extract was shown to lessen ALT levels in diabetic rats by Al-Amin et al. (2006), demonstrating that it may help treat the liver impairment carried on by diabetes.

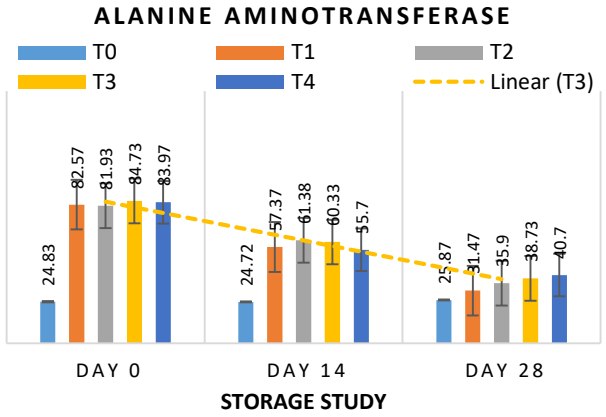

Figure 2. Effect on alanine aminotransferase (ALT) (µ/L).

***Effects on alkaline phosphatase (ALP) (µ/L)*:** The liver, bones, kidneys, and bile ducts are the chief locations for alkaline phosphatase (ALP), an indispensable enzyme intricate in dephosphorylation doings. Increased ALP levels frequently signify bone or liver harms. The effect of ginger and garlic extracts, both separately and together, on rats' ALP levels was evaluated during a 28-day period in the present study. A negative control (T_1), a control group (T_0), garlic extract (T_2), ginger extract (T_3), and amalgamation of garlic and ginger extracts (T_4) were among the treatments. The enzymatic activity over time was determined by measuring the levels of ALP on days 0, 14, and 28. Treatment, days, and their interaction have extremely substantial impacts on ALP levels ($p < 0.01$), rendering to the study of variance (ANOVA).

ALP levels rise during the progression of the 28-day period in all treatment groups, as seen in Fig. 3. From day 0 at 409.73±0.60 µ/L to day 28 at 550.56±0.05 µ/L, the control group (T_0) displayed a rise. Significantly, by day 28, the combined therapy group (T_4) had increased to 575.25±0.03 µ/L. These outcomes imply that extracts of ginger and garlic, particularly when combined, may finally affect ALP activity.

In difference to certain earlier research, a growth in ALP levels was seen. For example, rats given ginger extract (100 mg/kg) for two weeks displayed a marked rise in ALP levels, signifying a possible hepatotoxic impact. On the other hand, garlic extract dramatically lowered ALP levels, representing hepatoprotective qualities, according to Ahmad et al. (2023). Alterations in dosage, time, and the combined use of ginger and garlic extracts may be the cause of the inequality between previous trials and the present findings. An adaptive reaction to the bioactive substances found in ginger and garlic may be indicated by the rise in ALP levels seen in this study,

especially in the combo therapy group. It has been demonstrated that these ingredients, which include gingerol in ginger and allicin in garlic, alter liver function and enzyme activity.

But a rise of metabolic processes or modest hepatic stress could also be indicated by elevated ALP levels. Over a 28-day period, rats' ALP levels are noticeably impacted by the administration of ginger and garlic extracts, both separately and in combination. Because the joint treatment increased ALP activity the most, these consequences should be interpreted with caution. Even though the extracts are accepted to have health advantages, more research is necessary to regulate how they affect liver enzymes to safe and efficient use.

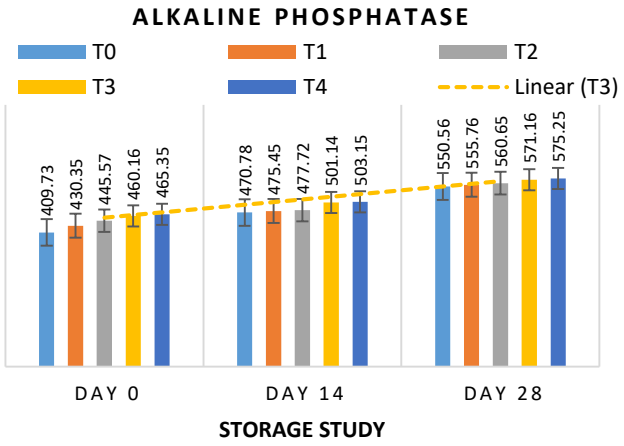

Figure 3. Effect on alkaline phosphatase (ALP) (µ/L).

***Effect on Blood glucose (mg/dL)*:** Blood glucose is one metabolic consequence that is seen in the blood. A diet high in carbs may effect in elevated amounts of glucose and other nitrogenous trashes. In fact, several studies have shown that eating foods with a higher glycemic index is connected to greater blood glucose levels than eating fewer carbohydrates. Significant alterations in blood glucose levels during a 28-day period were seen across the numerous treatment groups, according to the data in Fig. 4. In particular, the ANOVA consequences show that therapy, time, and their mixture have extremely significant effects on blood glucose levels ($p < 0.01$). All groups had analogous glucose levels at baseline (Day 0), ranging from 84.53 to 89.37 mg/dL. All groups indicated a significant increase in glucose levels on Day 14, with the T_4 group showing the largest rise (226.50±0.40 mg/dL). By Day 28, however, there was a noticeable drop in glucose levels, particularly in the T_3 group (99.27±0.21 mg/dL), which recommended that the therapies were having a hypoglycemic impact.

The amalgamation of ginger and garlic extracts (T_4) showed a substantial impact on blood glucose control. Though the T_4 group's glucose levels peaked on Day 14, they expressively dropped by Day 28 (97.50±0.40 mg/dL), signifying that these extracts may effort in performance to alter glucose metabolism. By Diurnal 28, the T_3 group (ginger extract only) demonstrated a stable drop in blood sugar levels, checking the hypoglycemic belongings of ginger as reported by Qadir et al. (2024). Furthermore, Qadir et al. (2024) shown how well ginger mechanisms to lower blood glucose levels in diabetic mice.

The bioactive constituents in garlic and ginger, such as allicin in garlic and gingerols in ginger, have been revealed to increase insulin sensitivity and cheer glucose absorption in peripheral tissues, which may be the source of the hypoglycemic possessions seen with these extracts. Studies displaying that these extracts can expand pancreatic β-cell commotion and modify significant enzymes intricate in glucose metabolism support these models. Therefore, using extracts of ginger and garlic may be an additional methodology for regulatory hyperglycemia, particularly when seeing diabetes mellitus.

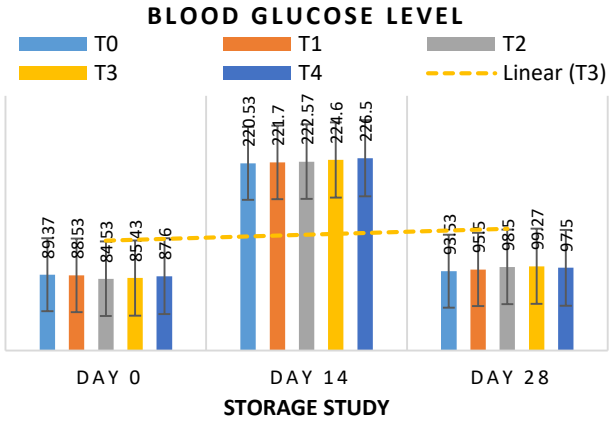

Figure 4. Effect on blood glucose (mg/dL).

***Effects on blood urea nitrogen (BUN) (mg/dL)*:** A waste product termed blood urea nitrogen (BUN) is created when proteins in the liver break down. The kidneys sieve it from the blood and eliminate it in urine. Kidney role may be obstructed by poorly managed blood glucose levels, as is the situation with diabetes. Blood urea nitrogen levels may rise as a result of impaired kidneys' inability to proficiently eradicate urea. Thus, upholding normal blood urea nitrogen levels and kidney function needs efficient blood sugar directive. Rats' BUN meditations are significantly stuck by treatment, days, and their interaction, according to the analysis of variance (ANOVA) for BUN levels, which is shown in Fig. 5 ($p < 0.01$). This recommends that blood urea nitrogen levels were considerably impacted by the type of action given as well as its duration. In specific, the BUN levels of the mixture therapy group (T_4), which was given both ginger and garlic extracts, increased gradually over time, triumph 25.70±0.20 mg/dL on day 28.

On the other hand, through the same time period, the BUN levels in the negative control group (T_1) decreased from 26.53±0.40 mg/dL on day 0 to 18.53±0.31 mg/dL on day 28. Understanding the possessions of the supplied extracts can be gained by distinct the treatment groups with the negative control (T_1) and control (T_0) groups. Over the progression of the trial, T_0's blood urea nitrogen levels remained relatively constant, but by day 28, T_1's levels had significantly fallen. By day 28, blood urea nitrogen levels in the garlic extract group (T_2) were rather decreased, whereas those in the ginger extract group (T_3) had ominously decreased. These consequences recommended that, in comparison to garlic extract alone, ginger extract might have a larger effect on dropping blood urea nitrogen levels. The mutual treatment group (T_4) proficient a prominent rise in blood urea nitrogen levels over time, which begs the question of whether the extracts of ginger and garlic work in concert.

Although both extracts had the capability to change BUN levels on their own, their combination did not produce the anticipated stabilizer or synergistic possessions. This might be the result of complicated interactions between the bioactive constituents found in ginger and garlic, which could variation kidney function or metabolism. The observed variations in blood urea nitrogen levels across several treatments and time periods are established to be very significant ($p < 0.01$) by the statistical analysis. This proves how the therapies given affect indicators of renal function. The combination therapy group's unanticipated rise in BUN levels 67 underlines the need for caution when anticipating combined herbal medicines since their interactions may have unexpected concerns.

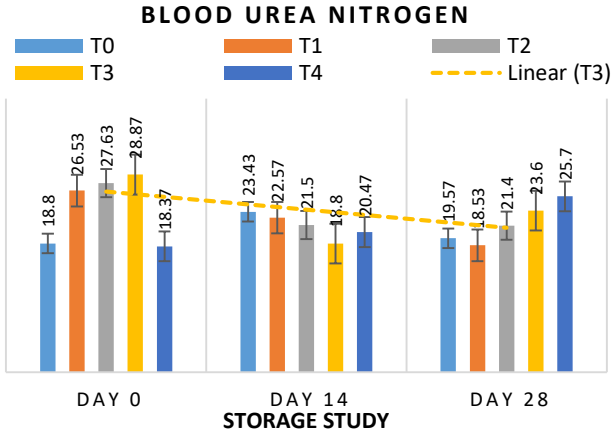

Figure 5. Effect on blood urea nitrogen (mg/dL).

***Effects on creatinine (mg/dL)*:** Subsequently creatinine is not enzymatically digested, it is produced as a significance of muscle breakdown. Creatinine is continuously produced and eradicated in urine because total creatinine levels are naturally stable. The body's strengths create creatinine, a waste creation that the kidneys eliminate. Creatinine is essential for tracing kidney function and identifying possible kidney damage in diabetics. Figure 6 shows the consequences of the study of creatinine concentrations, which display statistically significant alterations across treatments, time periods, and their connections ($p < 0.01$). Creatinine points in the control group (T_0) rise from 0.61±0.01 mg/dL to 0.88±0.01 mg/dL, then marginally reduced to 0.75±0.01 mg/dL.

At day 0, the creatinine deliberation in the harmful control group (T_1) was at its highest (0.98±0.01 mg/dL), and by day 28, it had dropped to 0.72±0.01 mg/dL. This conclusion indicated a partial recovery after an initial renal stress reaction, which may have been brought on by the lack of therapeutic interposition. Creatinine points reduced from 0.94±0.03 mg/dL at day 0 to 0.78±0.01 mg/dL at day 28 after action with garlic extract (T_2). Similarly, the ginger extract treatment (T_3) caused a significant reduction to 0.61±0.01 mg/dL, and a decline from 0.93±0.01 mg/dL to 0.83±0.02 mg/dL. From day 0 to day 28, the mutual treatment (T_4) showed a steady deterioration from 0.90±0.01 mg/dL to 0.88±0.01 mg/dL. These arrangements demonstrated that extracts of ginger and garlic, both discretely and in combination, improve kidney role over time.

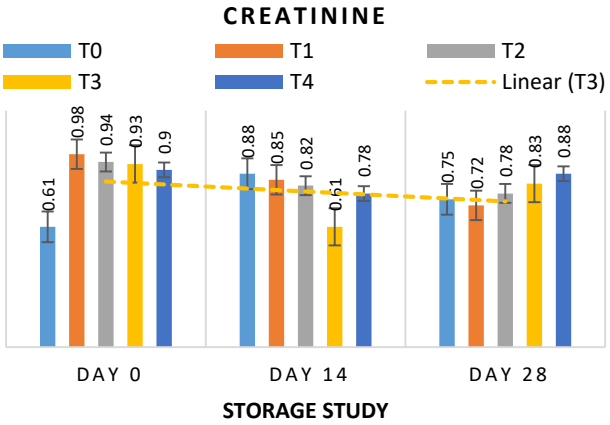

Figure 6. Effects on creatinine (mg/dL).

The amalgamation of ginger and garlic extracts (T_4) showed an important impact on blood glucose control. While the T_4 group's glucose levels peaked on Day 14, they significantly dropped by Day 28, proposing that these extracts may work in concert to modify glucose metabolism. By Day 28, the T3 group (ginger extract only) confirmed a steady drop in blood sugar levels, authorizing the hypoglycemic effects of ginger as reported by Qadir et al. (2024). Furthermore, Qadir et al. (2024) shown how well ginger works to lower blood glucose levels in diabetic rats. The noteworthy consequences from Figure 6, which show reductions in serum creatinine levels, support the efficiency of garlic and ginger extracts in enhancing renal function. The potential of these natural extracts as beneficial agents in controlling renal health is emphasized by the statistical significance ($p < 0.01$) across treatments and time periods.

***Effects on LDL (low density lipoprotein)*:** Low-density lipoprotein, or LDL, is one type of cholesterol that is devoted to as "bad" cholesterol. It can collect in artery walls and carry fat from the liver to cells, increasing the risk of heart attacks and strokes. Increases in LDL cholesterol in diabetes can consequence in plaque buildup that narrows blood vessels and raises the danger of stroke or cardiovascular issues. Treatment, days, and treatment vs. day interaction all had an extremely significant ($p < 0.01$) impact on rats' LDL concentrations, rendering to the data in Table 4. The control group (T_0) in Table 4. began with an LDL level of 44.27 mg/dL, scrabbled affectedly to 91.40 mg/dL, and then released to 60.50 mg/dL. Without any active interference, this variation revealed a brief point in cholesterol levels. At day 14, the negative control (T_1) had the maximum LDL interpretations, representing unprocessed diabetes-induced dyslipidemia. By day 28, however, a slight reduction was seen, most likely as a result of physiological adaptation.

Garlic extract (T_2) treatment augmented from 51.83 mg/dL to 90.50 mg/dL, then declined suggestively to 60.70 mg/dL on day 28. On the other hand, ginger extract (T_3) triggered LDL to drop quickly from 57.20 mg/dL on day 0 to 44.00 mg/dL on day 14, then rise to 61.30 mg/dL on day 28. When compared to discrete treatments, the combined treatment (T_4) showed enhanced LDL regulation, beginning at 44.27 mg/dL, summiting considerably at 61.50 mg/dL on day 14, and remaining slightly raised. In contrast to garlic (T_2) and the combination (T_4), which shown more reliable long-term management, ginger alone (T_3) was the most successful treatment in dropping LDL at day 14. The difference is between ginger's quick LDL lowering accomplishment and the combination extract's longer-lasting management. These outcomes recommend that while the combination provides a balanced long-term benefit, ginger displays a higher immediate reaction.

These consequences are supported by a research by Qadir et al. (2024) that showed that processed garlic and ginger dramatically lowered LDL levels in diabetic rats. Their study established that both worked better together to modify lipid profiles and enhance metabolic function in common. This supports our results, which showed that the combination treatment uninterruptedly kept LDL levels lower than the unprocessed diabetic control group.

***Effects on HDL (high density lipoproteins)*:** The "good" type of cholesterol is recognized as HDL, or high density lipoprotein. It drops the risk of heart disease and stroke by removing additional cholesterol from the passage and transporting it to the liver for waste. Lower HDL cholesterol levels are connected to diabetes mellitus. The composition of HDL is altered by DM, which diminishes its capacity to encourage opposite cholesterol transfer. Lower HDL levels are a result of increased high density lipoprotein catabolism carried on by diabetes mellitus. The possessions of several therapies on the levels of HDL in diabetic rats over a 28-day period are shown in Table 4. On day 14, HDL levels in the control group (T_0) showed a little deterioration, and by day 28, they had rather increased. The negative control group (T_1), on the other hand, demonstrated a steady rise in high density lipoprotein standards within the same time frame. Stimulatingly, HDL levels were significantly raised by treatments with garlic extract (T_2), ginger extract (T_3), and their mixture (T_4), with T_4 having the strongest effect.

The effects of time, therapy, and their amalgamation on high density lipoprotein levels were tremendously significant ($p < 0.01$), according to the ANOVA results in Table 4. This statistical significance highlights how well the remedies work to gradually alter high density lipoprotein concentrations. The combined treatment (T_4) continuously accomplished better than the individual treatments, demonstrating that the extracts of ginger and garlic work in concert.

The findings of Qadir et al. (2024), who originate that giving ginger and garlic powders to diabetic rats significantly increased serum high density lipoprotein deliberations in comparison to diabetic controls, are consistent with the observed increase in high density lipoprotein levels following garlic and ginger treatments. Their research lends authority to the idea that these extracts have hypolipidemic qualities that are advantageous for regulatory diabetes-related dyslipidemia.

The bioactive constituents in ginger and garlic, such as gingerols in ginger and allicin in garlic, have been established to modify lipid metabolism, which may be the reason of their hypolipidemic effects. These constituents may increase the amalgamation and function of high density lipoproteins by enhancing the activity of enzymes intricate in lipid transport and metabolism. Additionally, high density lipoprotein particles may be shielded from oxidative alteration by their antioxidant qualities, maintaining their commotion.

***Effects on VLDL (Very low density lipoprotein)*:** The liver yields a kind of cholesterol called VLDL (Very-Low-Density Lipoproteins), which are then squared into the bloodstream. Since it can lead to the expansion of cardiovascular illness, it is regarded as "bad" cholesterol. Raised VLDL levels can deteriorate insulin confrontation, which increases blood sugar levels and delays glucose uptake by cells. Because VLDL fat is atherogenic, it can raise the risk of cardiovascular sickness, a typical consequence of diabetes, by promoting the development of plaque in arteries. As shown in Table 4, the analysis of variance (ANOVA) for very low-density lipoprotein (VLDL) meditations shows that treatment, days, and their interaction have extremely significant effects.

The control group (T_0) showed a rise in VLDL levels from day 0 to the day 14, followed by a drop (24.27±0.15 mg/dL), according to the mean assessments in Table 4. The negative control group (T_1), on the other hand, retained continuously high VLDL levels above 23 mg/dL throughout all days. On day 14, the group that received ginger extract (T_3) indicated a noteworthy decrease in VLDL levels (19.21±0.58 mg/dL),

demonstrating that ginger may have the ability to alter lipid profiles. By day 28, the VLDL levels in the amalgamation treatment group (T_4) had similarly decreased, proposing that the extracts of ginger and garlic work in concert over time.

These consequences are consistent with earlier studies by Al-Amin et al. (2006), which institute that giving ginger and garlic powders to diabetic mice expressively improved their lipid profiles, including dropping their levels of low-density lipoprotein (LDL) and total cholesterol. According to the study, these seasonings' hypolipidemic qualities are caused by bioactive compounds that affect lipid metabolism. The latent of ginger and garlic as therapeutic agents in the management of diabetes-related dyslipidemia is emphasized by the consistency between the current results and those of Al-Amin. VLDL levels in diabetic rats were significantly affected by the management of garlic and ginger extracts, both distinctly and in amalgamation. The group that acknowledged ginger treatment showed the most pronounced possessions. These outcomes, which are supported by previous research, show the ordinary agents' therapeutic potential in the managing of dyslipidemia in diabetic settings.

***Effect on HbA1c (g/dL)*:** By evaluating the glycation of red blood cells, HbA1c provides an indication of the average blood glucose levels during the earlier two to three months. Given the around 120-day lifespan of red blood cells, HbA1c is an indirect indicator of sustained glucose parameter. It is frequently used as a common diabetes analytical and tracking method. HbA1c aids in determining the efficacy of treatment, particularly for type 2 diabetes. HbA1c testing is now advised by healthcare recommendations as a standard constituent of diabetic care. Significant differences between treatment groups and time periods are shown by the examination of HbA1c concentrations, which are shown in Table 4. All groups' HbA1c readings at baseline (day 0) were comparatively consistent, proposing similar beginning points. HbA1c levels in the T_4 group had significantly decreased by day 14 (4.38±0.06 g/dL), in difference to the negative control group's great levels (T_1: 6.85±0.14 g/dL). T_4 maintained decreased HbA1c values (4.36±0.03 g/dL) through day 28, continuing this trend and representing the long-lasting effects of the mutual extract treatment.

The possessions of the individual treatments were likewise positive. By day 14, the HbA1c levels of the ginger extract group (T_3) were significantly reduced, whereas the garlic extract group (T_2) had gradually reduced over the course of the 28-day period. These outcomes imply that ginger and garlic both have hypoglycemic possibilities, while ginger may have a quicker effect. The efficiency of garlic and ginger extracts in adapting glycemic control is confirmed by the notable differences in HbA1c levels seen between treatment groups and time periods. The enhanced performance of the combo treatment points to a synergistic interaction that needs more investigation. These results underline the therapeutic latent of integrating natural extracts into diabetes care approaches.

Table 4: Storage study of different parameter's level in rats.

Parameters	Storage period (days)	Treatments					Storage mean
		T_0	T_1	T_2	T_3	T_4	
Low density lipoprotein (LDL)	0	44.27^{k}	53.83^{i}	51.83^{j}	57.20^{h}	44.27^{k}	50.28
	14	91.40^{b}	92.47^{a}	90.50^{c}	44.00^{k}	61.50^{c}	75.97
	28	60.50^{f}	59.50^{g}	60.70^{ef}	61.30^{ef}	62.40^{d}	60.88
	Treatment mean	65.39	68.6	67.67	54.16	56.05	-
High density lipoprotein (HDL)	0	46.22^{d}	36.65^{m}	37.61^{k}	37.15^{l}	46.22^{d}	40.77
	14	40.62^{j}	41.45^{i}	42.19^{h}	46.22^{d}	44.20^{g}	42.93
	28	44.75^{f}	45.22^{e}	47.17^{c}	48.82^{b}	49.93^{a}	47.17
	Treatment mean	43.86	41.10	42.32	44.06	46.78	-
Very low density lipoprotein (VLDLP) level	0	18.71^{h}	31.53^{a}	31.58^{a}	31.67^{a}	18.74^{gh}	26.44
	14	30.15^{b}	29.90^{b}	28.76^{c}	19.21^{g}	25.85^{d}	26.77
	28	24.27^{e}	23.45^{f}	23.72^{f}	23.84^{ef}	23.88^{ef}	23.83
	Treatment mean	24.37	28.29	28.02	24.90	22.82	-
Platelets (x103/µL)	0	820.14^{o}	902.00^{h}	955.20^{g}	990.80^{c}	992.40^{d}	932.10
	14	822.34^{m}	845.00^{l}	867.40^{k}	888.20^{j}	890.10^{i}	862.60
	28	823.33^{n}	995.30^{c}	999.40^{a}	998.30^{b}	960.10^{f}	955.26
	Treatment mean	821.93	914.10	940.60	959.10	947.53	-
HbA1c (g/dL)	0	3.53^{j}	8.36^{b}	8.30^{b}	8.85^{a}	3.66^{j}	6.54
	14	7.18^{c}	6.85^{h}	6.36^{c}	3.90^{i}	4.38^{f}	5.73
	28	4.25^{fg}	$4.10g^{h}$	4.07^{h}	4.24^{fg}	4.36^{j}	4.20
	Treatment mean	4.98	6.43	6.24	5.66	4.13	-

Mean followed by different letters are significant ($p<0.05$); Each value is average of minimum three replicates

In a remarkable work, Simeon et al. (2011) observed the connection between plasma glucose standards and glycated hemoglobin (HbA1c) in Wistar rats with diabetes triggered by streptozotocin. After persuading diabetes with an intraperitoneal inoculation of streptozotocin at a dose of 70 mg/kg, the investigators observed the HbA1c and fasting plasma glucose levels. According to their outcomes, there was a significant linear relationship between higher HbA1c levels and increasing plasma glucose, demonstrating that HbA1c is a valid indicator for assessing long-term glycemic management in this rat model.

DISCUSSION

Significant alterations between treatments are shown by the Total Phenolic Content (TPC) analysis, which is shown in Table 2. The amalgamation management of ginger and garlic ($T_{Ginger+Garlic}$) had the maximum phenolic concentration, assessing 314.61 ± 0.02 mg GAE/g. This extraordinary number points to a potential synergistic interaction between allicin and gingerols, two favorable complexes found in both garlic and ginger. While ginger (T_{Ginger}) showed a comparatively lesser content of 100.41 ± 0.02 mg GAE/g, garlic only (T_{Garlic}) showed a substantial TPC of 155.85 ± 0.11 mg GAE/g. These consequences are consistent with those of Ghasemzadeh et al. (2010), who establish that garlic's antioxidant ability is recognized to its high content of phenolic chemicals, particularly allicin.

Hemoglobin is an orbicular protein that aids carry oxygen from the lungs during the course of the body. The ANOVA outcomes revealed extremely significant effects ($p < 0.01$) for treatment, days, and their interaction on hemoglobin ranks, as indicated in Table 3. Strong statistical confirmation that the types and length of treatment had a considerable impact on the Hb meditation is indicated by the extremely low p-values (0.0000) and high F-values. This over time authenticates the efficacy and dependability of the investigational treatments. Through the 28-day study period, the diabetic mice in the untreated group (T_1) sustained continuously low Hb levels, accumulative only slightly from 11.95±0.03 to 12.01±0.06 g/dL, as seen by the mean comparison facts in Table 3. Hb points, on the other hand, significantly enhanced in rats given garlic (T_2), ginger (T_3), or a combination of the two (T_4). For illustration, the T_4 group's hemoglobin improved the maximum, from 11.95±0.03 g/dL on day 0 to 15.14±0.02 g/dL on day 28. While ginger alone (T_3) improved Hb levels from 11.75±0.02 to 13.96±0.07 g/dL, management with only garlic (T_2) raised levels from 11.84±0.02 to 14.23±0.02 g/dL. These conclusions imply that while ginger and garlic both have hemopoietin potentials on their own, they work best when organized. These consequences are reliable with those of Asdaq and Inamdar (2010), who found that the antioxidant and antidiabetic possessions of garlic and ginger supplementation greatly improved hematological limitations in diabetic rats.

Similar hematological compensations of ginger and garlic were also prominent in a study by Islam and Choi (2008) in rats with diabetes caused by alloxan. The antioxidant qualities of these botanicals were found to increase RBC, Hb, and packed cell volume (PCV) values. The dosage and length of treatment are where our results and those of Islam and Choi (2008) diverge most. The present study's larger dosage (6 g/kg BW) over 28 days led to higher RBC counts, predominantly in the combination group (T_4), indicating more dramatic efficiency, even though both studies verified hematological developments. These outcomes imply that extracts from ginger and garlic may diminish the effects of diabetes-induced anemia. The beneficial potential of these natural substances is confirmed by the consistently rising RBC counts and extremely significant statistical standards.

Immune cells known as white blood cells (WBCs) aid in protecting the body in contradiction of diseases. Granules comprehending protein-based enzymes are seen in certain WBCs known as granulocytes. The WBC amount decreased from 9.04±0.02 to 6.82±0.01 after treatment with only garlic (T_2), and from 9.22±0.01 to 6.87±0.02 after treatment with ginger (T_3). The mixture in T_4 showed a synergistic effect, resulting in the maximum reduction in increased WBC levels, even though both solitary treatments were beneficial. This configuration is consistent with research by Tariq et al. (2021), who establish that extracts from ginger and garlic have anti-inflammatory and immunomodulatory possessions that enable diabetic rats' WBC levels return to normal. The size of the response is a significant difference between the cited study and the current one. Although Tariq et al. noted some minor modifications, the current study found that WBC amounts decreased more sharply and progressively, mainly in the T_4group.

This strength be because the current study used a larger dose (6 g/kg BW) and a longer treatment period. Extracts of ginger and garlic, especially when united, dramatically lowered increased WBC levels in diabetic rats, indicating potent immune-regulatory and anti-inflammatory possessions. These outcomes show how natural dietary changes can be used therapeutically to manage diabetes's immune-related difficulties. The efficacy of these plant extracts in reducing WBC abnormalities is confirmed by the regularly observed treatment trends and very significant statistical consequences. The consequences of platelets are reliable with those of a 2009 study by El-Sabban that examined the antithrombotic possessions of garlic in diabetic rats. According to their findings, garlic stopped abnormal platelet count elevation and decreased platelet accumulation. Similarly, ginger's active constituents, such as gingerol, have been shown to prevent platelet beginning. The existing data show a larger regulatory consequence than their study, particularly in the combination group (T_4), which may be because of differences in dosage and treatment period. In diabetic mice, the extracts of ginger and garlic, predominantly when combined, helped normalize increased platelet levels and lower the hazard of thrombosis. Because of the exceptionally low p-values and low mean square error (0.1), the outcomes were statistically extremely significant. These results lend credence to the therapeutic effect of dietary botanicals in reducing cardiovascular risk and regulating platelets in diabetic conditions.

The percentage of red blood cells (RBCs) in the entire capacity of blood is known as the hematocrit. It is a fundamental sign of the body's ability to conveyance oxygen. Low hematocrit values could show blood loss or anemia. Elevated levels may be a sign of polycythemia or dehydration. In a complete blood count (CBC) test, it is frequently restrained. Over the course of 28 days, the influence of ginger and garlic extracts on diabetic rats' hematocrit (HCT) levels was evaluated. Treatment, days, and treatment-day interaction had a highly significant ($p < 0.01$) impact on HCT levels, according to the ANOVA consequences in Table 3.

Anti-inflammatory and antioxidant potentials found in both ginger and garlic may have helped to repair erythropoietin activity and lessen oxidative impairment to red blood cells. These consequences are consistent with earlier studies showing the hematological compensations of ginger and garlic. For example, a study by Qadir et al. (2024) presented that giving diabetic rat's powdered ginger and garlic greatly improved a number of blood indicators, counting HCT levels. According to the study's results, by strengthening antioxidant resistances and lowering oxidative stress, these natural enhancements may help manage the difficulties of diabetes.

The consequences are consistent with previous readings showing that ginger and garlic have hepatoprotective possessions. For instance, a study by Thomson et al. (2007) indicated that giving diabetic mice extracts of ginger and garlic significantly improved their liver enzyme profiles, including their AST levels. According to the study's findings, by establishment antioxidant emplacements and lowering oxidative stress, these natural supplements may help achieve the difficulties of diabetes.

The amalgamation of ginger and garlic (T_4) produced the maximum obvious improvement in AST levels when compared to the individual treatments, indicating a synergistic effect. The combined antioxidant potentials of both basils may be responsible for this improvement, as they may lessen oxidative destruction to liver cells and stimulate hepatic function. The effectiveness of these extracts in treating diabetes-induced hepatic changes is established by the notable alterations between the treatment groups and the diabetic control group.

The protective influence of these natural extracts against diabetes-induced liver injury was shown by the fact that the diabetic control group (T_1) revealed persistently raised ALT levels through the research, whilst the healthy control group (T_0) maintained stable levels. According to a study by Thomson et al. (2007), for instance, garlic extract's antioxidant qualities were liable for the considerable decrease

in blood ALT levels in streptozotocin-induced diabetic mice. Likewise, ginger extract was shown to lessen ALT levels in diabetic rats by Al-Amin et al. (2006), demonstrating that it may help treat the liver impairment carried on by diabetes.

In difference to certain earlier research, a growth in ALP levels was seen. For example, rats given ginger extract (100 mg/kg) for two weeks displayed a marked rise in ALP levels, signifying a possible hepatotoxic impact. On the other hand, garlic extract dramatically lowered ALP levels, representing hepatoprotective qualities, according to Ahmad et al. (2023). Alterations in dosage, time, and the combined use of ginger and garlic extracts may be the cause of the inequality between previous trials and the present findings. An adaptive reaction to the bioactive substances found in ginger and garlic may be indicated by the rise in ALP levels seen in this study, especially in the combo therapy group. It has been demonstrated that these ingredients, which include gingerol in ginger and allicin in garlic, alter liver function and enzyme activity.

But a rise of metabolic processes or modest hepatic stress could also be indicated by elevated ALP levels. Over a 28-day period, rats' ALP levels are noticeably impacted by the administration of ginger and garlic extracts, both separately and in combination. Because the joint treatment increased ALP activity the most, these consequences should be interpreted with caution. Even though the extracts are accepted to have health advantages, more research is necessary to regulate how they affect liver enzymes to safe and efficient use.

Blood glucose is one metabolic consequence that is seen in the blood. A diet high in carbs may effect in elevated amounts of glucose and other nitrogenous trashes. In fact, several studies have shown that eating foods with a higher glycemic index is connected to greater blood glucose levels than eating fewer carbohydrates. Significant alterations in blood glucose levels during a 28-day period were seen across the numerous treatment groups, according to the data in Figure 4. In particular, the ANOVA consequences show that therapy, time, and their mixture have extremely significant effects on blood glucose levels ($p < 0.01$). All groups had analogous glucose levels at baseline (Day 0), ranging from 84.53 to 89.37 mg/dL. All groups indicated a significant increase in glucose levels on Day 14, with the T_4 group showing the largest rise (226.50±0.40 mg/dL). By Day 28, however, there was a noticeable drop in glucose levels, particularly in the T3 group (99.27±0.21 mg/dL), which recommended that the therapies were having a hypoglycemic impact.

The amalgamation of ginger and garlic extracts (T_4) showed a substantial impact on blood glucose control. Though the T_4 group's glucose levels peaked on Day 14, they expressively dropped by Day 28 (97.50±0.40 mg/dL), signifying that these extracts may effort in performance to alter glucose metabolism. By Diurnal 28, the T_3 group (ginger extract only) demonstrated a stable drop in blood sugar levels, checking the hypoglycemic belongings of ginger as reported by Qadir et al. (2024). Furthermore, Qadir et al. (2024) shown how well ginger mechanisms to lower blood glucose levels in diabetic mice.

A waste product termed blood urea nitrogen (BUN) is created when proteins in the liver break down. The kidneys sieve it from the blood and eliminate it in urine. Kidney role may be obstructed by poorly managed blood glucose levels, as is the situation with diabetes. Blood urea nitrogen levels may rise as a result of impaired kidneys' inability to proficiently eradicate urea. Thus, upholding normal blood urea nitrogen levels and kidney function needs efficient blood sugar directive. Rats' BUN meditations are significantly stuck by treatment, days, and their interaction, according to the analysis of variance (ANOVA) for BUN levels, which is shown in Figure 5 ($p < 0.01$). This recommends that blood urea nitrogen levels were considerably impacted by the type of action given as well as its duration. In specific, the BUN levels of the mixture therapy group (T_4), which was given both ginger and garlic extracts, increased gradually over time, triumph 25.70±0.20 mg/dL on day 28.

Although both extracts had the capability to change blood urea nitrogen (BUN) levels on their own, their combination did not produce the anticipated stabilizer or synergistic possessions. This might be the result of complicated interactions between the bioactive constituents found in ginger and garlic, which could variation kidney function or metabolism. The observed variations in blood urea nitrogen levels across several treatments and time periods are established to be very significant ($p < 0.01$) by the statistical analysis. This proves how the therapies given affect indicators of renal function. The combination therapy group's unanticipated rise in BUN levels 67 underlines the need for caution when anticipating combined herbal medicines since their interactions may have unexpected concerns.

Subsequently creatinine is not enzymatically digested, it is produced as a significance of muscle breakdown. Creatinine is continuously produced and eradicated in urine because total creatinine levels are naturally stable. The body's strengths create creatinine, a waste creation that the kidneys eliminate. Creatinine is essential for tracing kidney function and identifying possible kidney damage in diabetics. Figure 6 shows the consequences of the study of creatinine concentrations, which display statistically significant alterations across treatments, time periods, and their connections ($p < 0.01$). Creatinine points in the control group (T_0) rise from 0.61±0.01 mg/dL to 0.88±0.01 mg/dL, then marginally reduced to 0.75±0.01 mg/dL.

The amalgamation of ginger and garlic extracts (T_4) showed an important impact on blood glucose control. While the T_4 group's glucose levels peaked on Day 14, they significantly dropped by Day 28, proposing that these extracts may work in concert to modify glucose metabolism. By Day 28, the T_3 group (ginger extract only) confirmed a steady drop in blood

sugar levels, authorizing the hypoglycemic effects of ginger as reported by Qadir et al. (2024). Furthermore, Qadir et al. (2024) shown how well ginger works to lower blood glucose levels in diabetic rats. The noteworthy consequences from Figure 6, which show reductions in serum creatinine levels, support the efficiency of garlic and ginger extracts in enhancing renal function. The potential of these natural extracts as beneficial agents in controlling renal health is emphasized by the statistical significance ($p < 0.01$) across treatments and time periods

Garlic extract (T_2) treatment augmented from 51.83 mg/dL to 90.50 mg/dL, then declined suggestively to 60.70 mg/dL on day 28. On the other hand, ginger extract (T_3) triggered LDL to drop quickly from 57.20 mg/dL on day 0 to 44.00 mg/dL on day 14, then rise to 61.30 mg/dL on day 28. When compared to discrete treatments, the combined treatment (T_4) showed enhanced LDL regulation, beginning at 44.27 mg/dL, summiting considerably at 61.50 mg/dL on day 14, and remaining slightly raised. In contrast to garlic (T_2) and the combination (T_4), which shown more reliable long-term management, ginger alone (T_3) was the most successful treatment in dropping LDL at day 14. The difference is between ginger's quick LDL lowering accomplishment and the combination extract's longer-lasting management. These outcomes recommend that while the combination provides a balanced long-term benefit, ginger displays a higher immediate reaction.

The consequences are supported by a research by Qadir et al. (2024) that showed that processed garlic and ginger dramatically lowered LDL levels in diabetic rats. Their study established that both worked better together to modify lipid profiles and enhance metabolic function in common. This supports our results, which showed that the combination treatment uninterruptedly kept LDL levels lower than the unprocessed diabetic control group.

The findings of Qadir et al. (2024), who originate that giving ginger and garlic powders to diabetic rats significantly increased serum high density lipoprotein deliberations in comparison to diabetic controls, are consistent with the observed increase in high density lipoprotein levels following garlic and ginger treatments. Their research lends authority to the idea that these extracts have hypolipidemic qualities that are advantageous for regulatory diabetes-related dyslipidemia. The bioactive constituents in ginger and garlic, such as gingerols in ginger and allicin in garlic, have been established to modify lipid metabolism, which may be the reason of their hypolipidemic effects. These constituents may increase the amalgamation and function of high density lipoproteins by enhancing the activity of enzymes intricate in lipid transport and metabolism. Additionally, high density lipoprotein particles may be shielded from oxidative alteration by their antioxidant qualities, maintaining their commotion.

The consequences are consistent with earlier studies by Al-Amin et al. (2006), which institute that giving ginger and garlic powders to diabetic mice expressively improved their lipid profiles, including dropping their levels of low-density lipoprotein (LDL) and total cholesterol. According to the study, these seasonings' hypolipidemic qualities are caused by bioactive compounds that affect lipid metabolism. The latent of ginger and garlic as therapeutic agents in the management of diabetes-related dyslipidemia is emphasized by the consistency between the current results and those of Al-Amin. VLDL levels in diabetic rats were significantly affected by the management of garlic and ginger extracts, both distinctly and in amalgamation. The group that acknowledged ginger treatment showed the most pronounced possessions. These outcomes, which are supported by previous research, show the ordinary agents' therapeutic potential in the managing of dyslipidemia in diabetic settings.

In a remarkable work, Simeon et al. (2011) observed the connection between plasma glucose standards and glycated hemoglobin (HbA1c) in Wistar rats with diabetes triggered by streptozotocin. After persuading diabetes with an intraperitoneal inoculation of streptozotocin at a dose of 70 mg/kg, the investigators observed the HbA1c and fasting plasma glucose levels. According to their outcomes, there was a significant linear relationship between higher HbA1c levels and increasing plasma glucose, demonstrating that HbA1c is a valid indicator for assessing long-term glycemic management in this rat model.

***Conclusion*:** Based on the above findings, the study demonstrates that ginger and garlic extracts, both individually and in combination, exert significant protective and restorative effects in diabetic rats. The treatments improved key hematological parameters, including Hb, RBC, HCT, and platelet counts, indicating mitigation of diabetes-induced anemia and normalization of coagulation profiles. Additionally, WBC counts were reduced, suggesting anti-inflammatory and immune-modulatory effects. Hepatic biomarkers (ALT, AST, and ALP) showed marked improvement, reflecting hepatoprotective properties, while reduced creatinine levels indicated renal protection. These effects are largely attributed to the antioxidant, anti-inflammatory, and metabolic-regulating properties of the phytochemicals present in ginger and garlic.

The interventions also significantly improved lipid and glycemic profiles. Both ginger and garlic lowered LDL and VLDL while increasing HDL concentrations, thereby reducing cardiovascular risk factors. HbA1c levels were drastically reduced, indicating enhanced long-term glycemic control. Among the treatment groups, ginger extract (T_3) and the garlic-ginger combination (T_4) consistently outperformed the diabetic control group, with the combination often showing synergistic benefits. Collectively, the results confirm that ginger and garlic, alone or together, can be potent natural

therapeutic agents for managing diabetes and its associated hematological, hepatic, renal, and metabolic complications.

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***SDGs Addressed*:** Good Health and Well-Being; Industry, Innovation and Infrastructure through promoting phytochemical-based innovation in health sciences and Responsible Consumption and Production by encouraging safe.

***Policy Referred*:** WHO Global Diabetes Compact; national NCD and diabetes prevention/control programs; WHO Traditional Medicine Strategy and herbal medicine regulations.

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